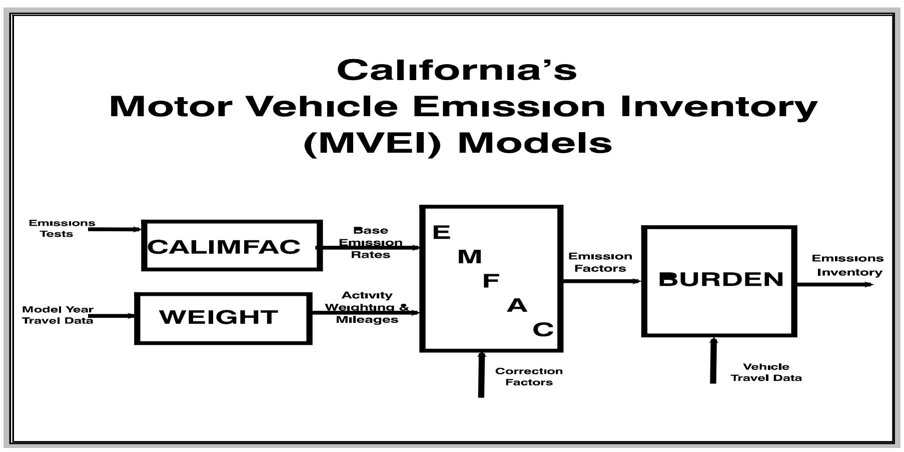
Section 3.0 Overview

Staff previously estimated on-road motor vehicle emissions using a series of computer models called the MVEI models. The following discussion provides an overview of the emission estimating process and the computer models used. Although some technical detail is included, this discussion is intended to provide more of a qualitative understanding of the overall process. For a more comprehensive discussion of the workings of the MVEI7G model, documentation is available in "***Methodology for Estimating Emissions from On-Road Motor Vehicles (Volumes 1-6),*** *and* ***Derivation of Emission and Correction Factors for MVEI7G.***" These documents are available on the ARB's Web Page at: http://www.arb.ca.gov/msei/mvei/mvei.htm.

Figure 3-1 is a block diagram of the four computer models utilized in MVEI7G. A brief description of the four models follows:

Figure 3-1 – MVEI7G



The primary function of the **CALIMFAC** model was to provide basic emission rates (BERs) to EMFAC. CALIMFAC also simulates various vehicle inspection and maintenance (I/M) program (smog check) scenarios, and adjusts the BERs, accordingly. These BERs are based on dynamometer tests of randomly selected vehicles driven over a specific driving pattern called the U.S. EPA Federal Test Procedure (FTP). CALIMFAC estimates BERs for model years 1965 through 2003 and four broad I/M scenarios.

EMFAC adjusted the BERs for non-standard driving conditions. These adjustments are generally referred to as correction factors. Correction factors include, but are not limited to, speed, temperature, fuel, and driving cycle.

The **WEIGHT** model estimated the contribution each model year makes to a given calendar year's activity. Because the BERs and correction factors are model year-specific, it is critical that the appropriate model year activity assigned to each model year's emission factor is properly weighted.

BURDEN used county-specific activity data to estimate emissions at the county and air basin level. The three main types of activity data are: the population of vehicles (POP), the number of vehicle miles traveled (VMT), and the number of vehicle starts (Starts). The corresponding emission rates are expressed as grams per vehicle, grams per mile, and grams per start. An inventory is then calculated by multiplying the emission factor by its associated activity.

The first three models used statewide data. In contrast, the BURDEN model produced emission inventories for the entire state, an air basin, or county. The models incorporate emission impacts of only those regulations adopted prior to the model release date and not regulations proposed for adoption. The MVEI Models estimated emissions for calendar years 1970 through 2020.

Vehicle Classes and Technology Groups

The MVEI7G model provided emission estimates for ten different vehicle classes and three technology groups that were combined to form 19 class/technology groups. The technology groups are non-catalyst equipped (NCAT), catalyst equipped (CAT), and diesel powered (DSL) vehicles. The nineteen class/technology groups, and the abbreviations used are listed in Table 3-1.

TABLE 3-1. - 19 VEHICLE CLASS/TECHNOLOGY GROUPS IN MVEI7G

CLASS#	Class	Tech Groups	Vehicle Class (spelled out)
1	LDA	NCAT, CAT, DSL	Light-Duty Autos
2	LDT	NCAT, CAT, DSL	Light-Duty Trucks
3	MDT	NCAT, CAT, DSL	Medium-Duty Trucks
4	LHGT	NCAT, CAT, DSL	Light-Heavy Gas Trucks
5	LHDT	DSL	Light-Heavy Diesel Trucks
6	MHGT	NCAT, CAT	Medium-Heavy Gas Trucks
7	MHDT	DSL	Medium-Heavy Diesel Trucks
8	HHDT	DSL	Heavy-Heavy Diesel Trucks
9	UBD	DSL	Urban Transit Buses
10	MCY	NCAT	Motorcycles

Exhaust Emission Sources

Emissions that emanate from the vehicle's tailpipe are called exhaust emissions. Incomplete combustion of the fuel is the primary cause of HC, CO, and PM emissions. These emissions occur at all times, but especially when the air/fuel ratio is richer than stoichiometric (14.7-to-1) conditions, such as during a hard acceleration. NO_X is produced during combustion at high temperatures and pressures, but especially under lean air/fuel ratio conditions. Properly working catalysts reduce tailpipe emissions from gasoline vehicles by over 90 percent when combined with electronic systems that monitor the air/fuel ratio. Due to higher combustion temperatures, excess air and high pressures, a diesel-fueled vehicle emits comparatively more NO_X than a comparable gasoline-fueled vehicle. PM is the by-product of incomplete combustion. The lean overall air/fuel ratios used by diesel vehicles preclude the use of conventional reduction catalysts for emissions control.

There are two vehicle operation modes that contribute to exhaust emissions: the stabilized running mode and the start mode. The stabilized running mode occurs when the engine and/or catalyst are at normal operating temperature. As defined for modeling purposes, the start mode occurs during the first 100 seconds of operation after the engine has been started. Since the engine and/or catalyst may not have achieved their optimal operating temperature, the emissions during starts are generally higher.

Most of the PC, LDT and MDT exhaust data used for modeling are collected in ARB Surveillance programs. In developing MVEI7G, data from approximately 2600 vehicles were available. Most vehicles were tested on a dynamometer, which simulates on-road driving. Because HDT engines may be sold independent of the chassis, HDT engines are tested on engine dynamometers, which simulate the load experienced by the engine. Individual vehicle parameters such as axle ratio, aerodynamics and gross vehicle weight are represented rather crudely by the engine dynamometer test.

Evaporative Emissions Sources

Gasoline readily leaks or evaporates from the fuel storage and delivery system. This occurs whether the vehicle is running or not and whether the ambient temperature is increasing or decreasing. The evaporative emission processes are described below:

1) Diurnal

Diurnal emissions result from evaporation in the fuel system and breakthrough of vapors from the carbon canister, hoses and connectors when the vehicle is not being operated and the ambient temperature is rising.

2) Hot Soak

Hot soak emissions result when vapors escape within one hour after the engine is turned off. These emissions are caused by high under-hood and fuel temperatures.

3) Resting Losses

Resting loss emissions are defined as losses due to permeation of fuel through rubber and plastic components when the vehicle has not been operated for at least an hour and the ambient temperature is either constant or decreasing.

4) Running Losses

Running losses occur when hot fuel vapors escape from the fuel system or overwhelm the carbon canister while a vehicle is being operated.

Evaporative emissions are measured using a Sealed Housing Evaporative Determination (SHED) Test. This test is performed by placing a vehicle in an airtight enclosure, also referred to as a shed, to capture the evaporating gases. The temperature inside the shed is varied to simulate changes in ambient temperature. A running loss enclosure, a dynamometer within a shed, is used to gather emissions while a vehicle is being driven.

Activity

The BURDEN model utilized a variety of motor vehicle activity data developed from a variety of sources. Since MVEI7G produced county-specific and vehicle class-specific emission inventories, county-specific and vehicle class-specific activity data were needed. Activity data forecasting methods were also needed to project activity from a baseline year to 51 calendar years, 1970 to 2020. The sources of baseline activity data were often different than the sources of forecasting data. In many cases, data needed to be disaggregated from a statewide to county-specific level, or disaggregated from the entire motor vehicle fleet to specific vehicle classes. The most relevant activity data and their primary sources are summarized in Table 3-2.

TABLE 3-2. - COUNTY-SPECIFIC ACTIVITY DATA AND SOURCES

Data Type	Primary Data Sources
Populations	DMV, DOF
Vehicle Miles Traveled	CALTRANS, TDMs, ARB
Vehicle Starts	U.S. EPA, ARB
Ambient Temperatures	NWS, ARB, Districts, DWR
VMT by Speed Distribution	CALTRANS, TDMs
Soak Distribution	U.S. EPA, ARB
Activity Distribution	U.S. EPA, ARB

Population

For MVEI7G, vehicle registration data from the DMV were used for vehicle population estimates for calendar years 1970 through 1993. Since the DMV uses different classifications and vehicle weight-classes, the data from these reports were first converted to match ARB’s vehicle classes. Projections of light-duty vehicle population for future years were made using the DOF growth rates of people population for each county.

Projections for HDTs were based on CALTRANS' truck growth rates from the MVSTAFF report.

Vehicle Miles Traveled (VMT)
In MVEI7G, VMT on state highways and other roadways was estimated for the total motor vehicle fleet by CALTRANS and published in its yearly MVSTAFF Report. 1980 to 1993 reports were used. Since BURDEN required VMT data by vehicle class, other sources of information (such as DMV registration data) were used in conjunction with the MVSTAFF report to estimate travel by vehicle class. VMT estimates were first made for HDTs, UBDs, and MCYs. This subtotal was then subtracted from the total VMT in the MVSTAFF Report and the remainder was split among LDAs, LDTs, and MDTs using vehicle population data for these classes. The COGs in most urbanized areas have developed TDMs. As part of the transportation planning process, these models estimate VMT for their regions for some classes of vehicles. When available, VMT estimates from these local TDMs were used in place of MVSTAFF.

All HDT VMT was estimated using two sources: CALTRANS' yearly report, "Truck Miles of Travel on the California State Highway System" and Pacific Environmental Services' (PES) "Assessment of Heavy-Duty Gasoline and Diesel Vehicles in California: Population and Use Patterns." The PES Report contains data regarding travel on local roads. The VMT for all HDTs were then split for gasoline and diesel HDTs using data from the PES Report.

Projections for future years are also given in the MVSTAFF Report and from the TDMs. Since these sources may not have included projections for all of the years needed by the MVEI Models, staff interpolated and/or extrapolated the data as needed.

Vehicle Starts
In MVEI7G, the on-road emission inventory used an estimated number of starts to calculate trip emissions for all gasoline-powered vehicle classes except heavy-duty trucks and motorcycles. The total number of vehicle starts was calculated as the product of a per-vehicle start rate (starts per vehicle per day) and the fleet population. Data from the U.S. EPA's 3-City Instrumented Vehicle Study, along with estimates of trips from CALTRANS travel surveys, were analyzed by staff to estimate the statewide, per vehicle start rates for light-, and medium-duty vehicles. Vehicles in the U.S. EPA's study were instrumented to record the number of times the vehicles were started each day. This study was conducted in 1992 and included 1978 to 1992 vehicles. Since 35 model years were used in the MVEI Models for LDAs (25 model years for the other vehicle classes), CALTRANS' travel survey data were used to fill in for the remaining model years.

CALTRANS periodically conducts a statewide travel survey in which people record their driving habits in diaries. Because CALTRANS is interested in the number of *trips* people make, non-destination trips are not recorded. These non-destination trips include short side trips, and starts associated with shuffling cars at home or moving a car in a parking lot. Since emissions are produced whenever a vehicle is started, the CALTRANS survey data were adjusted to include these starts. The analysis resulted in the distribution of starts by vehicle age used in MVEI7G. When combined with the population distribution by vehicle age, a fleet average start rate was produced. For LDAs, the statewide average number of starts per vehicle per day was estimated as 6.35. Previously, (EMFAC7F), this rate was assumed to be 3.76 trips per vehicle per day using only the CALTRANS Survey Data. Therefore, the ratio of MVEI7G "starts" to EMFAC7F "trips" for LDAs was estimated at 1.69 and this ratio was used as the "trips-to-starts" adjustment factor.

Some regions use TDMs to provide the ARB with alternative estimates of the total number of trips, independent of the total number of vehicles, so that a per vehicle trip rate was not used. For these regions, the total number of trips predicted by the TDMs was multiplied by the 1.69 adjustment factor to produce the total number of starts. Therefore, the rate of starts per vehicle varied from year-to-year for regions that have TDMs. For regions that did not use TDMs, the survey data were used to determine the region-to-statewide relative trip rates. These regional differences were used to adjust the total number of starts for each region.

Ambient Temperatures

Because emissions from motor vehicles are sensitive to temperature, profiles of ambient temperatures are used to estimate seasonal inventories. Staff analyzed ambient temperature data from the following sources: ARB and district monitoring stations, the National Weather Service, and two databases which are maintained by the California Department of Water Resources - CIMIS and CDEC. A single temperature distribution was created by averaging the hourly temperatures from the 10 days with the worst air quality during the period of 1987 to 1989.

For non-attainment areas, the ten worst days were determined for each pollutant. For ozone, the ten worst days were determined for the entire basin (i.e., all the counties within the basin have the same ten worst days). For CO, NO_2, and SO_2, the ten worst days were determined for each county or a portion of a county within an air basin.

Because attainment areas do not have exceedance days, the ten days were based on the worst air quality readings (basin-wide for O_3, countywide for CO). For the unclassified areas (areas with limited or no air quality data), the ten days were based on a neighboring county within the same air basin that had available data.

VMT by Speed Distribution

The primary sources of VMT by speed distribution are CALTRANS and, where available, regional TDMs. Speed distribution data from TDMs were used in BURDEN without further adjustment. For areas that did not use TDMs, staff used CALTRANS traffic count data and information from the HPMS database to estimate VMT by speed. The same VMT by speed distribution was used for all vehicle classes except buses. Travel data were provided by the TDMs for a base year and usually several future years, each with different speed distributions. Staff used these speed distributions for those analysis years, and interpolated for the years between. Areas without TDMs used the same speed distributions for all calendar years.

For urban diesel transit buses, the VMT by speed distribution was based on a study performed for the ARB by Valley Research Corporation titled "On-Road Motor Vehicle Activity Data, Volume 1-Bus Population and Activity Pattern." The study analyzed the driving patterns of transit buses and school buses using chase cars equipped with data loggers. Although the study was done in the SCAB, the resultant speed distributions were used for all counties in the state after adjusting for each county's urban and small urban classifications.

Starts by Soak Time Distribution

A "soak" is defined as the time during which a vehicle is turned off, to the time it is restarted. Start emission rates differ according to how long a vehicle has been "soaking" and MVEI7G produced start emission factors for a variety of pre-start soak times. Staff analyzed data from the U.S. EPA's Instrumented Vehicle Study to group starts by soak duration for 12 pre-start intervals. Since the U.S. EPA data included the time of day the vehicles were started, the analysis produced a different soak distribution for each of six periods. However, the same soak distributions by period were used for all calendar years, for light-, and medium-duty vehicles, and for all counties.

Period Splits

Because BURDEN estimated emissions for each of six time periods, the activity data used by BURDEN was estimated for each period. While the ambient temperature data were derived by time of day, other activity data (VMT, starts, and VMT by speed) were derived for an average day and then disaggregated into six time periods. These divisions were based on CALTRANS or COG estimates of VMT for certain periods of the day (for VMT), miles of roadway by functional classification, and vehicle speed profiles by functional classification for VMT by speed distribution. Driver trips-in-motion by region of the State were used to allocate trips to period of the day.

3.1 **Annual Average Inventory**

EMFAC2000 produces a number of seasonal inventories for different purposes. Seasonal adjustments in the model include ambient temperature, humidity and the Reid Vapor Pressure of dispensed fuel.

Episodic inventories are needed to assess worst case conditions for ozone, high ambient temperature and low relative humidity, and carbon monoxide, low ambient temperature and high relative humidity, in order to estimate how effective adopted or proposed emission reductions strategies will be in reducing peak concentrations of pollutants. EMFAC2000 produces both episodic and month specific inventories, however, an annual average inventory is best suited for assessing emission trends over time.

MVEI7G did not produce an annual average emissions inventory, rather ozone and carbon monoxide episodic estimates were weighted together for this purpose. A two thirds weighting for ozone and one third weighting for carbon monoxide was used in MVEI7G for all air basins with the exception of the South Coast, where a 7/12, 5/12 weighting was used for ozone and carbon monoxide, respectively. The weighting of episodic inventories may have led to an overestimation of annual average emissions.

In EMFAC2000, annual average inventories are derived by weighting each month of emissions for the year equally for a specific area. It is believed that this modification in methodology yields a more realistic basis for tracking emission reductions and assessing the cost of effectiveness.